(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 550 973 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 92311245.2

(51) Int. Cl.[5]: G02B 6/42

(22) Date of filing: 10.12.92

(30) Priority: 10.01.92 US 819252

(43) Date of publication of application:
14.07.93 Bulletin 93/28

(84) Designated Contracting States:
DE FR GB

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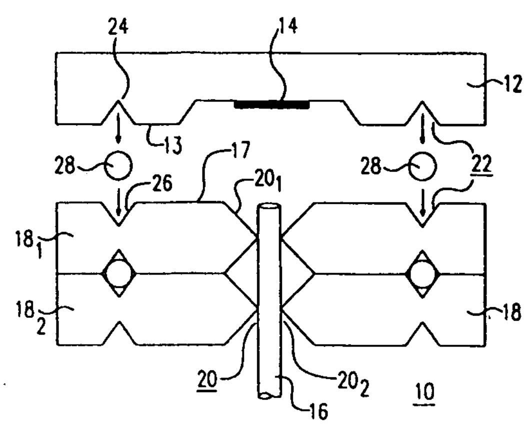
(54) Self-aligned optical subassembly.

(57) An optical subassembly is disclosed which provides self-alignment between an active optical device (14) and associated optical elements (16,82). In particular, the subassembly comprises a first substrate member (12) which is utilized to support the active optical device. A separate plurality of substrate members (18) is used to form a support for the associated optical elements (i.e., fiber, coupling lens or both), where the separate members are stacked, one on top of the other, and an aperture (20) through the center thereof utilized to support the optical elements. The aperture may be formed to include a mechanical stop (70) suitable for fixing the location of an optical fiber endface. Alignment fiducials (22) formed on the device support member and the stack provide self-alignment therebetween, as well as physical attachment of the support member to the stack. The various substrate members may comprise any suitable material including, but not limited to, silicon, metal, or molded plastic.

FIG. 1



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Background of the Invention

Technical Field

The present invention relates to an optical subassembly and, more particularly, to an optical subassembly which provides alignment between an active optical device and associated optical elements.

Description of the Prior Art

In the realm of optical device packaging, there is beginning to develop a number of assemblies which utilize a single crystal semiconductor material (such as silicon) as the support structure for the various optical devices. Often referred to as "silicon optical bench" technology, the utilization of silicon may result in a significant cost saving in optical packaging over some of the more esoteric materials which have been used in the past. More importantly, silicon processing technology has advanced to the stage where a number of relatively standard procedures (e.g., oxidation, metallization, etching - isotropic or anisotropic) may be utilized to facilitate attachment of the devices to the support member, as well as alignment therebetween. Further, it is possible to form optical waveguiding structures directly in/on a silicon substrate, resulting in the ability to form a completely operable optical subassembly in silicon.

An exemplary utilization of silicon in the formation of a subassembly for optoelectronic devices is disclosed in U. S. Patent 4,945,400 (Blonder et al.) issued July 31, 1990 and assigned to the assignee of record in this application. In general, Blonder et al. disclose a subassembly including a semiconductor (e.g., silicon) base and lid including a variety of etched features (e.g., grooves, cavities, alignment detents) and metallization patterns (e.g., contacts, reflectors) which enable the optoelectronic device to be reliably and inexpensively mounted on the base and coupled to a communicating optical fiber. In particular, Blonder et al. disclose an arrangement wherein the optoelectronic device (e.g., LED) is disposed within a cavity formed by a lid member and the communicating fiber is positioned along a groove formed in a base member. A reflective metallization is utilized to optically couple the device to the fiber. Therefore, positioning of the device over the reflector is the only active alignment step required to provide coupling. Any remaining alignments are accomplished utilizing fiducial features formed in the base and lid members.

Although the Blonder et al. subassembly represents a significant advance in the field of silicon optical bench packaging, a need remains for providing an arrangement which does not require active alignments. In particular, the provision of a completely passive optical packaging arrangement is considered both more reliable and less expensive than virtually any alternative requiring active alignment between components.

Summary of the Invention

The problems remaining in the prior art are addressed by the present invention which relates to an optical subassembly and, more particularly, to an optical subassembly which provides alignment between an active optical device and associated optical elements, as further defined by the appended claims.

Brief Description of the Drawing

FIG. 1 illustrates an exemplary optical subassembly formed in accordance with the teachings of the present invention;
FIG. 2 illustrates a plan view of an exemplary optical device support member;
FIG. 3 illustrates a selected cross-section view of the member of FIG. 2;
FIG. 4 illustrates a plan view of exemplary member utilized to form the stack;
FIG. 5 illustrates an exemplary stack utilizing a plurality of members as illustrated in FIG. 4;
FIG. 6 illustrates an alternative stack arrangement;
FIGs. 7-11 illustrate an exemplary fabrication process for forming a fiber mechanical stop within an exemplary silicon stack member; and
FIG. 12 illustrates an alternative embodiment of the present invention incorporating a spherical lens and fiber mechanical stop within the subassembly.

Detailed Description

FIG. 1 illustrates, in an exploded view, an exemplary optical subassembly 10 formed in accordance with the teachings of the present invention. As shown, optical subassembly 10 comprises a first member 12 which is utilized as the support member for an active semiconductor optical device 14. An optical fiber 16 is illustrated in FIG. 1 as being coupled to optical device 14. In accordance with the teachings of the present invention, optical fiber 16 is mechanically supported by a stack of members 18, disposed as shown in FIG. 1. Exemplary optical subassembly 10 utilizes a pair of members 18_1 and 18_2 to form stack 18. Optical fiber 16 is inserted through an aperture 20 within stack 18, where aperture 20 comprises a pair of viaholes 20_1 and 20_2 formed completely through each member 18_1 and 18_2, respectively.

Stack 18 is aligned with, and mated to, support member 12 by a plurality of alignment fiducials 22. In the exemplary embodiment of optical subassembly 10, alignment fiducials 22 comprise a first plurality of detents 24 formed in surface 13 of member 12 and a second plurality of detents 26 formed in surface 17 of stack 18, where detents 26 are formed to align with associated detents 24. A plurality of spherical members 28 are disposed between first plurality 24 and second plurality 26 to provide mechanical attachment between support member 12 and stack 18. Therefore, since the detents are accurately formed in a pattern predetermined to provide the required alignment, optical fiber 16 will be self-aligned to active optical device 14 when stack 18 is fixed to support 12, as indicated by the directional arrows in FIG. 1.

A plan view of an exemplary optical device support member 12 is shown in FIG. 2. In this particular embodiment, optical device 14 is illustrated as disposed within a recess 30 (see FIG. 3) formed in top surface 13 of member 12. Alternatively, optical device 14 may simply be attached to the planar top surface 13 of support member 12. A first metal layer 32 is formed on surface 13 and coupled to device 14 to provide a first electrical contact to the optical device. A second metal layer 34 is formed to provide the remaining contact. A wirebond 36 is used to provide the electrical connection between metal layer 34 and the top side 15 of optical device 14. Subsequent to the formation of metal layers 32,34, a leadframe section (not shown) may be attached to metal layers 32,34 of support member 12 to provide the final electrical leads associated therewith.

A set of three alignment fiducials 24, in the form of pyramidal detents, are illustrated in exemplary support member 12 of FIG. 2, where the detents are arranged such that a stable mechanical attachment is achieved. It is to be understood that any suitable number of such alignment fiducials, including kinematic designs, may be utilized when practicing the present invention.

FIG. 3 contains a selected cross-section view in perspective of exemplary support member 12 as depicted in FIG. 2. Shown in particular in this view is exemplary recess 30, formed to a predetermined depth d_1 below surface 13 of member 12. Depth d_1 may be chosen such that optical device 14, upon subsequent attachment, remains fully recessed below surface 13. Detents 24 are shown as formed to include a surface width w and a depth d_2 sufficient to accommodate an alignment sphere of known proportions. When utilizing silicon in the formation of member 12, recess 30 and detents 24 may be formed by etching, using appropriate masking of top surface 13. Alternatively, when utilizing a plastic, these features may be included in the mold, or formed as a secondary operation upon the molded piece part. In accordance with the self-aligning feature of the present invention, exemplary alignment fiducials 24 are formed at a predetermined distance D from the center of recess 30. Optical device 14 may then be accurately positioned within recess 30, with respect to first metal layer 32, using a liquified amount of solder which will conformally coat the underlying pattern of first metal layer 32. The surface tension of the liquid material will cause the optical device to center itself and thus become aligned with metal layer 32. Therefore, by the appropriate choice of distance D and the subsequent coaxial placement of the associated stack alignment fiducials (see FIG. 4), optical alignment will be achieved.

A plan view of an exemplary stack member 18_i is illustrated in FIG. 4. A viahole 20_i is shown as being formed completely through member 18_i. When utilizing silicon as the member, both the top surface 17 and bottom surface 19 (visible in FIG. 5) may be etched to form the viahole. The utilization of a conventional anisotropic etchant (EDP or KOH, for example) may result in the formation of an unwanted knife-edge 23 (see FIG. 5) within viahole 20_i. However, such an etch may be required to form the desired physical design of the alignment detents. A set of three such exemplary detents 26 are illustrated as formed in top surface 17 of member 18_i, where detents 26 are formed to align with detents 24 of member 12 upon mating.

FIG. 5 illustrates an exemplary stack 18 comprising separate members 18_1, 18_2, 18_3. A plurality of knife-edges 23, which may be formed when performing a single step, anisotropic etch upon silicon support members, are clearly visible in this view. The individual members forming stack 18 may be joined using the technique described above for joining stack 18 to member 12. That is, a plurality of detents 42 may be formed in each member 18_i, as shown, with a plurality of spherical members 44 used to physically align the separate pieceparts. Thermionic or anodic bonding may be used to fix this attachment.

An alternative stack arrangement, which avoids the formation of knife-edges, may be utilized in accordance with the teachings of the present invention. FIG. 6 illustrates a top plan view of an exemplary stack member including a viahole 50, etched in <110> silicon so as to form opposing parallel faces 52, 54 and opposing tapered faces 56, 58. A pair of such members may be stacked, with one member rotated orthogonal to the other such As shown, each individual members forming the stack is fabricated to include a viahole 50 comprising opposing parallel faces 52, 54 and opposing tapered faces 56, 58. A pair of such members may then be stacked, with one rotated orthogonal to the

other, as shown by the via 50' illustrated in phantom in FIG. 6. The orthogonal displacement of the the pair of members results in the such intersection of parallel faces 52, 54, 52' and 54' of viaholes 50 and 50' forming a "box", as indicated by the heavy line in FIG. 6. A fiber 16 may then be constrained within the dimension of the box as outlined by these parallel surfaces without the concern of a knife-edge formation.

Alternatively, appropriate etching and masking steps may be used to avoid the formation of knife edges. Additionally, the fabrication process may be used to form a mechanical stop for a fiber endface within the stack. FIGs. 7-11 depict a particular series of such steps utilized with an exemplary silicon stack member 18. Referring to FIG. 7, oxide layers 60 and 62 are first grown over top and bottom surfaces 17 and 19 of member 18, respectively. Oxide layers 60 and 62 are subsequently patterned and etched to expose the underlying silicon in windows 64 and 66, where window 64 comprises a width w_1 somewhat less than the width w_2 of window 64, the difference in width calculated to form the desired fiber mechanical stop (as will be evident from the subsequent processing operations). The structure as depicted in FIG. 7 is then etched for a predetermined period of time so as to form openings 65 and 67, as shown in FIG. 8, where each is formed to a depth d, leaving a relatively small thickness t of silicon therebetween. Referring to FIG. 9, a first oxide layer 68 is subsequently grown over top surface 17, as well as etched opening 65, of member 18. Similarly, a second oxide layer 70 is grown over bottom surface 19 and etched opening 67. As is well-known in the silicon processing art, the formation of a thermal oxide layer involves the inward movement of the oxide at the silicon/oxide interface, as the underlying silicon consumed. Advantageously, the removal of the silicon during this process results in rounding knife edges 23 (see FIG. 3) and forming rounded corners 69,71 as shown in FIG. 9. The rounded profiles of these areas thus reduces the problems (e.g., damage to fiber) associated with knife edges. Oxide layer 70 is subsequently removed, and via opening 67 is further etched until oxide layer 68 is reached, where oxide 68 will act as a natural etch stop. The structure at this point in the process is illustrated in FIG. 10. Upon removal of the remaining oxide material, stack member 18 is configured as shown in FIG. 11. As shown, a mechanical stop 74 for a fiber 16 is formed at the interface between the top and bottom etched regions, where the size of opening 76 is controlled (by controlling, for example, window widths, etchants, various etch parameters) so as to allow the core region of a fiber 16 to be coupled to the active area of an associated optical device (not shown).

As mentioned above, a spherical coupling lens may be included in a subassembly formed in accordance with the teachings of the present invention. FIG. 12 illustrates an exemplary embodiment 80 of the present invention including such a lens. In particular, subassembly 80, as shown in FIG. 2, includes a lens 82 resting upon top surface 84 of a fiber stack 86, where the upper most member 86_1 of stack 86 is formed to include a recess 90 sufficient to capture lens 82. Additionally, member 86_1 is processed to include a fiber stop 92, using the oxide growth and etch steps outlined above in associated with FIGs. 7-11. Therefore, an optical fiber 94 may be inserted through an aperture 96 within stack 86 and the endface 98 of fiber 94 will be fixed by the location of mechanical stop 92. In an alternative arrangement, lens 82 may be positioned within aperture 96, below top surface 84, as shown in phantom in FIG. 12.

It is to be understood that the above-described embodiments of the present invention are exemplary only. For example, the various substrate members described above may be formed from a plastic material which is suitably molded utilizing either injection-molded or transfer-molded technologies. Some applications, particularly where cost is of a concern, plastic may be the material of choice. Indeed, the preferred alternative may utilize a silicon support member for the active device (for thermal management purposes) and a plastic stack (for cost reduction purposes). Further, various types of alignment fiducials, other than the above-described detent/sphere combination, may be used. For example, alignment grooves and ridges may be formed in the adjacent surfaces and interlocked to provide the physical attachment. Various other means will be apparent to those skilled in the art and are considered to fall within the scope of the present invention.

Claims

1. An optical subassembly comprising

   a first substrate member (12) including a major surface for supporting an optical device (14), said first member further including a plurality of alignment fiducials (24) formed in said major surface (13) and positioned at predetermined lociations; and

   a plurality of substrate members (18) disposed to form a stack defined as including a major surface (17), each member comprising a viahole (20) formed through the thickness thereof such that when the plurality of members are joined, the plurality of viaholes are aligned and form an aperture therethrough, said stack further comprising a plurality of

fiducials (26) formed in said major surface and disposed to align with the first member fiducials such that when said stack is mated with said first member, optical alignment is achieved.

2. A subassembly as defined in claim 1 wherein the first member alignment fiducials comprise a plurality of detents formed in the major surface and the stack alignment fiducials comprise a like plurality of detents formed in the stack major surface, and wherein a plurality of spherical members may be disposed therebetween to provide mechanical attachment and alignment.

3. A subassembly as defined in claim 1 or 2 wherein the stack is formed to support either an optical fiber (16) through the aperture thereof, or a spherical lens member (82), said lens being aligned with the active optical device location on the first substrate member, the sperical lens member being either supported in the major surface of the stack, or within the stack aperture.

4. A subassembly as defined in claim 1, 2 or 3, wherein the stack is formed to include a mechanical stop (70) within the stack aperture, said mechanical stop suitable for fixing the location of an optical fiber within the stack, and/or the first substrate support member is formed to include a recess below the major surface, said recess for supporting the said optical device.

5. An optical subassembly as defined in any one preceding claim, wherein each substrate member comprises silicon, and/or the first member alignment fiducials are formed by etching the major surface of said first member, the plurality of viaholes and alignment fiducials of the stack being formed by etching the appropriate surfaces of the separate silicon substrates formed said stack, said etching optionally including anisotropically etching the major surface of the stack and member.

6. An optical subassembly as defined in claim 5, wherein a selected silicon substrate member of the plurality of members comprising the stack is etched to include a mechanical stop within the associated viahole, the mechanical stop suitable for fixing the location of an optical fiber within the stack aperture.

7. An optical subassembly as defined in any one preceding claim, wherein at least one of the substrate members is of plastic, the latter being optionally injection-molded plastic members, or transfer-molded plastic members.

8. A method of forming an optical subassembly comprising the steps of:

a) providing a first substrate member (12), said first member including a major surface (13) for supporting an active optical device;
b) forming a plurality of alignment fiducials (24) in the major surface of said first member at predetermined locations thereof;
c) providing a plurality of substrate members (18), each member including a top and bottom major surface;
d) forming a viahole (20) completely through each substrate member of said plurality of members provided in step c);
e) forming a plurality of alignment fiducials (26) in the major surface of a selected member of the plurality of members, the alignment fiducials positioned to align with the alignment fiducials in the first substrate member formed in step b); and
f) stacking the plurality of substrate members such that the plurality of viaholes align and form an aperture therethrough.

9. The method according to claim 8, wherein the method comprises the further steps of:

g) attaching a semiconductor active optical device (e.g transmitting device) to the first substrate member;
h) locating at least one optical device within the aperture formed in step f); and
i) attaching the first substrate member to the stacked plurality of members such that the alignment fiducials are aligned and mated; and/or in performing (g),
g_1) forming a recess in the top major surface of the first substrate member; and
g_2) disposing the semiconductor active optical device within the recess formed in step g_1); and/or in performing (h), locating an optical fiber (16) or a spherical lens (82) or both in tandem within the stack aperture.

10. The method according to claim 8 or 9, wherein in performing step (d), a mechanical fiber stop is formed within selected viahole by the following steps:

d_1) oxidizing the top and bottom major surfaces of a selected substrate member;
d_2) patterning the oxide and etching to expose a recess of width w_1 in the top major surface and a recess of width w_2 in the bottom major surface where the windows are coaxial and $w_1 < w_2$;

d_3) reoxidizing the etched structure of step c_2);

d_4) removing the oxide from the bottom major surface and etching through the recess until contacting the top surface oxide layer; and

d_5) removing the remaining oxide and providing a fiber stop at the intersection of the recesses.

11. A method according to claim 8, 9 or 10, wherein the substrate members are of silicon and/or plastic.

FIG. 1

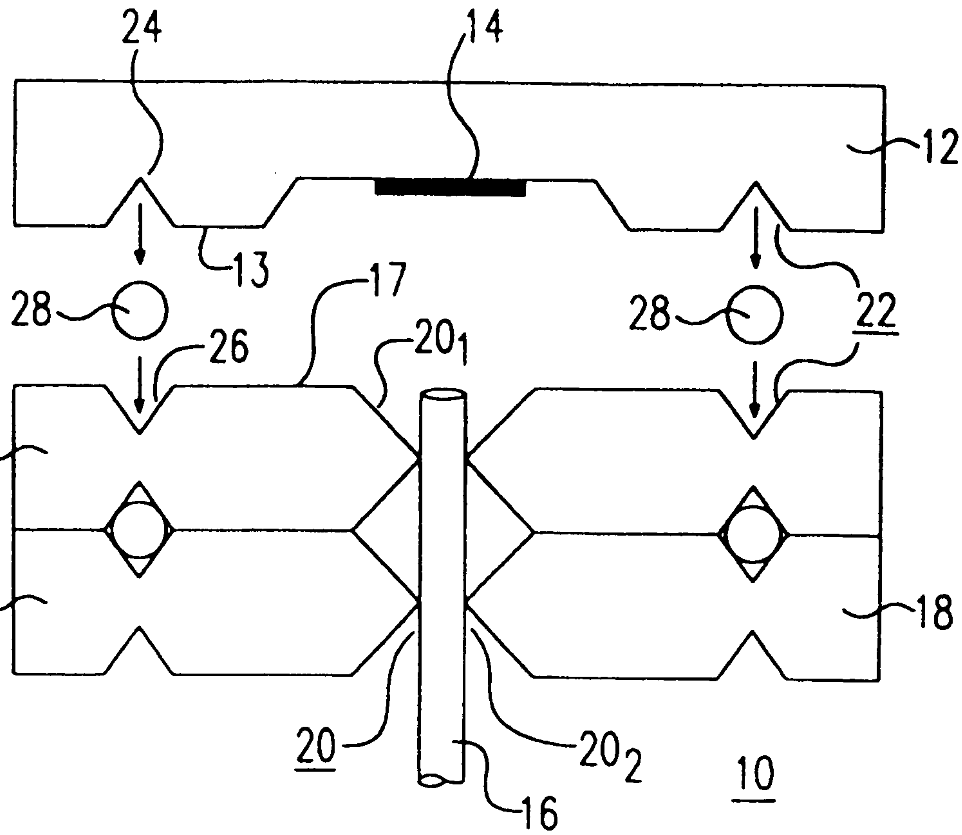
24
14
12
13
17
28
26
20_1
28
22
18_1
18_2
18
20
20_2
10
16

FIG. 2

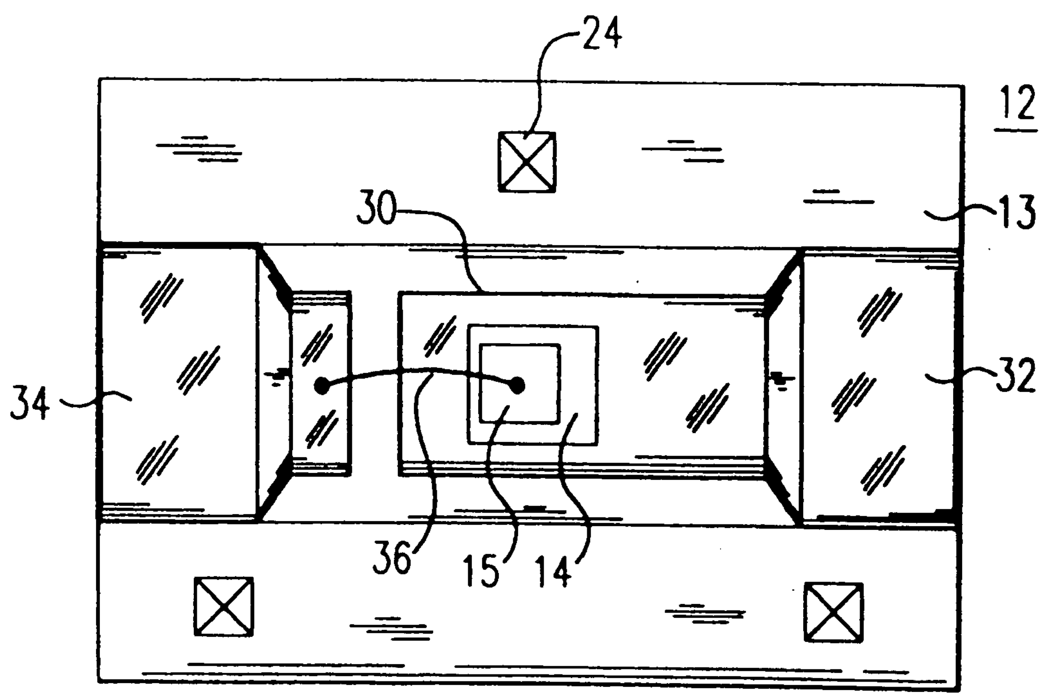
24
12
30
13
34
32
36
15
14

FIG. 3

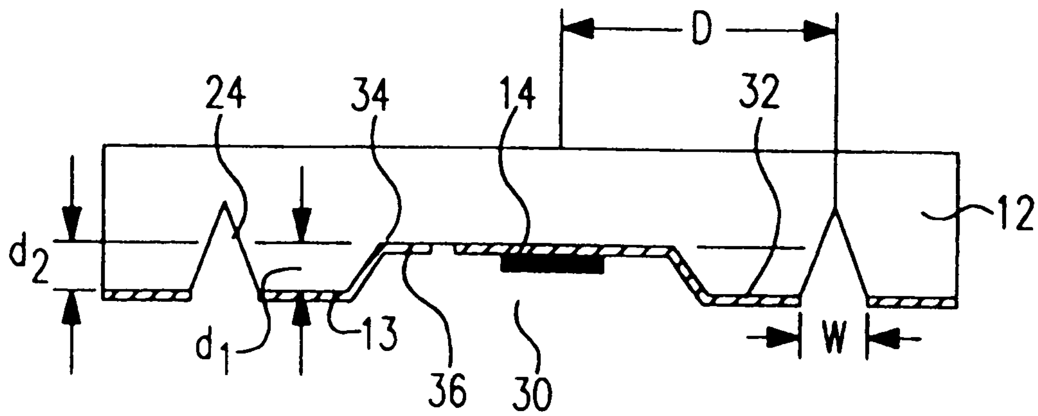

FIG. 4

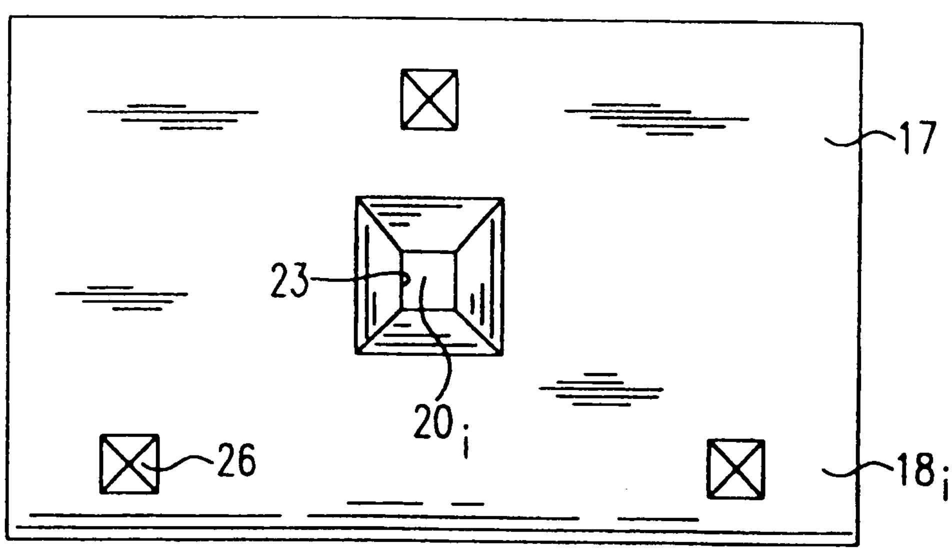

FIG. 5

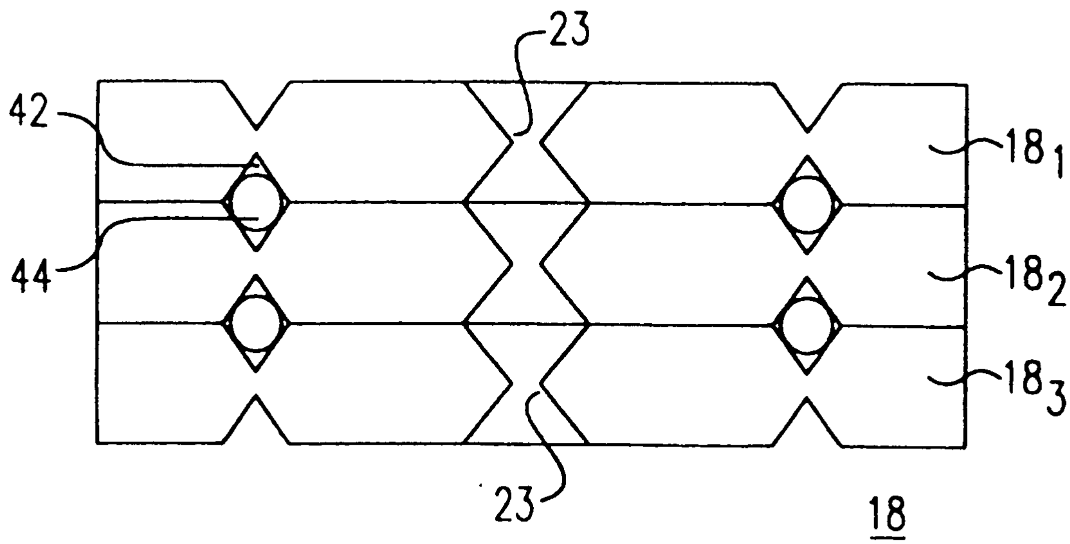

FIG. 6

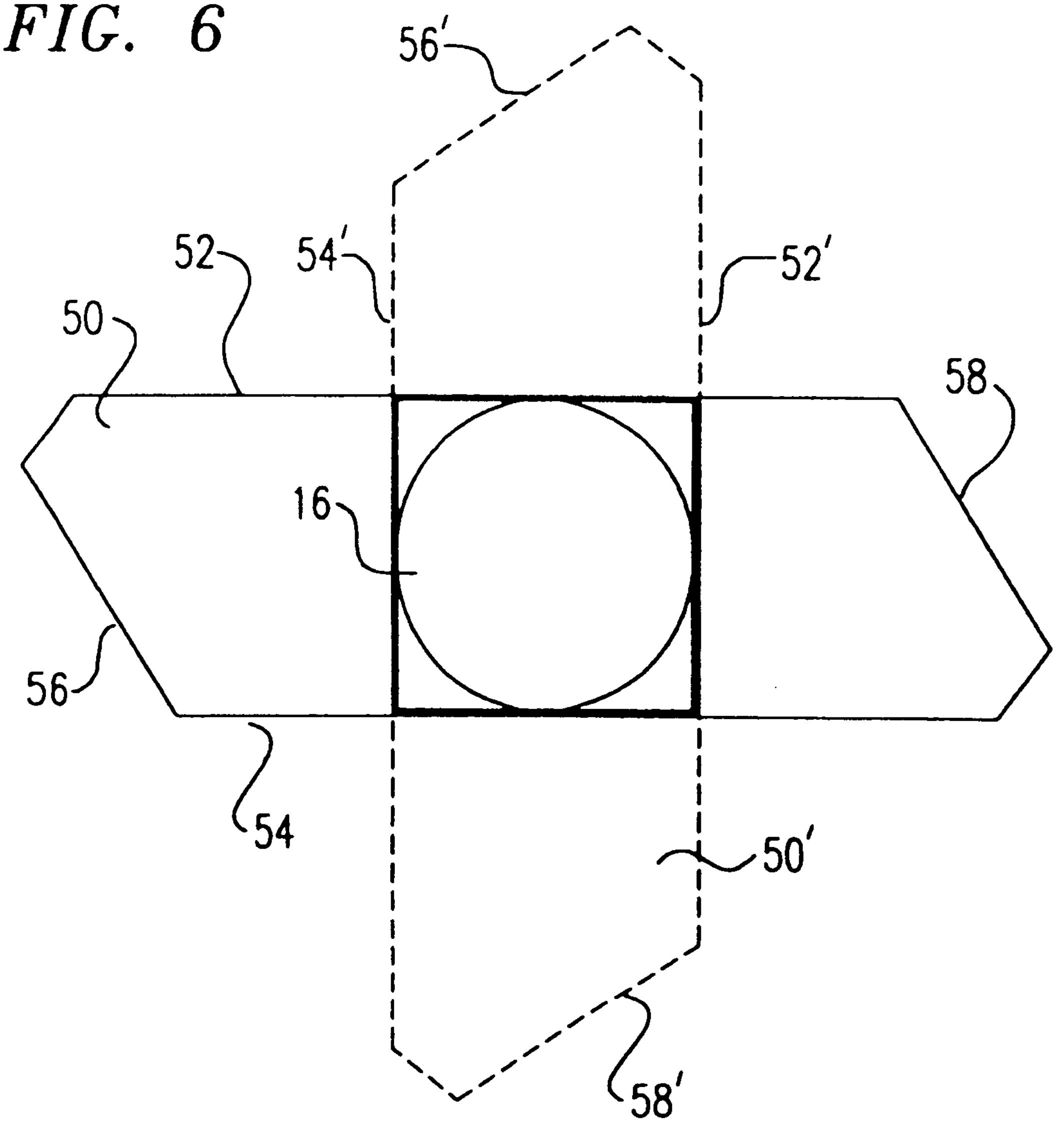

FIG. 7

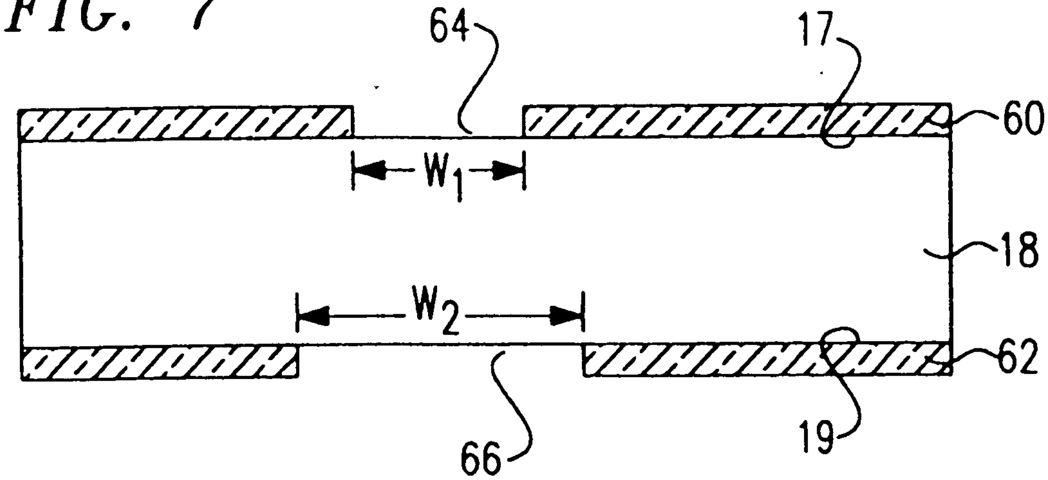

FIG. 8

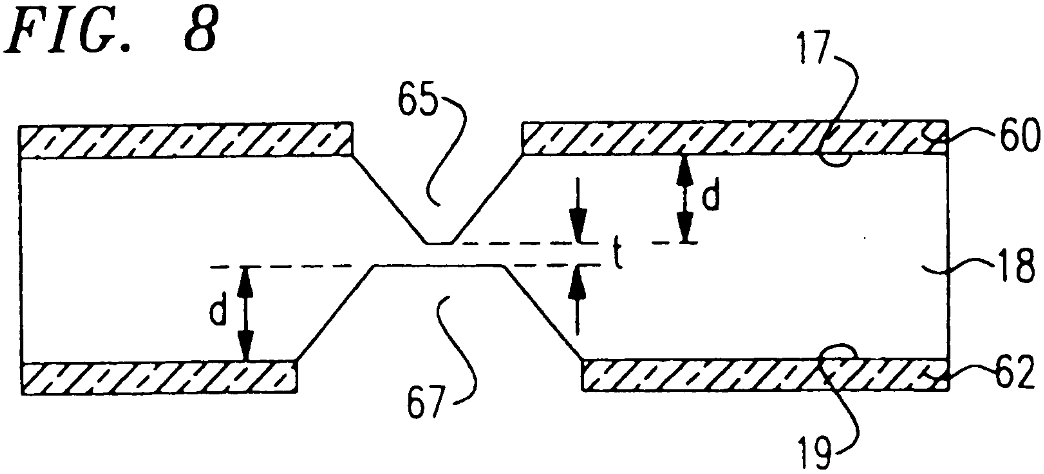

FIG. 9

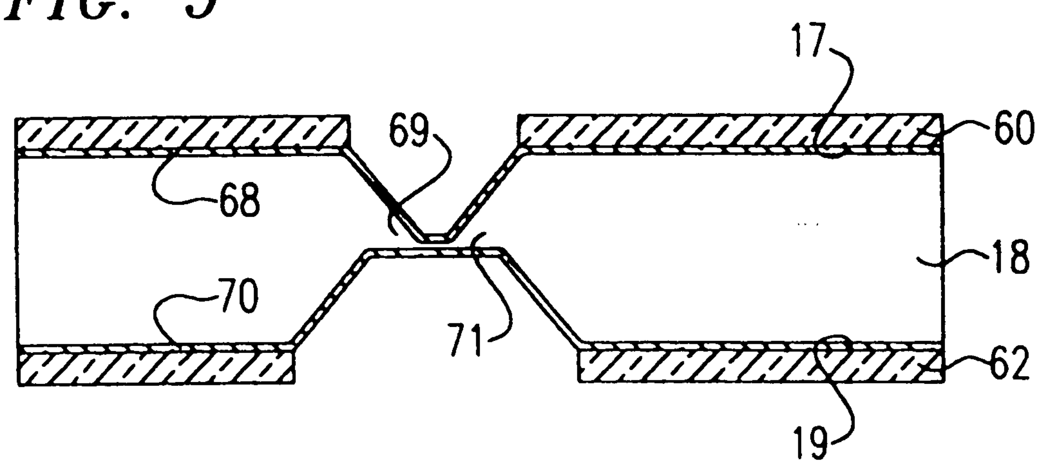

FIG. 10

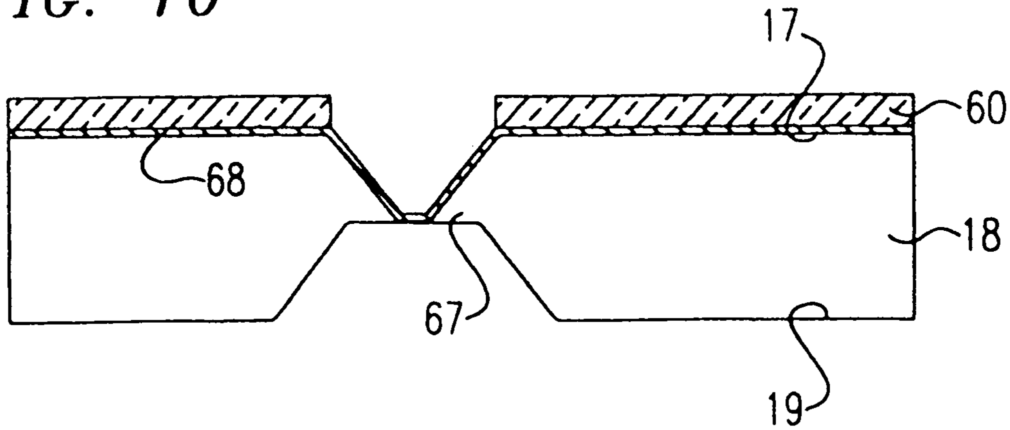

FIG. 11

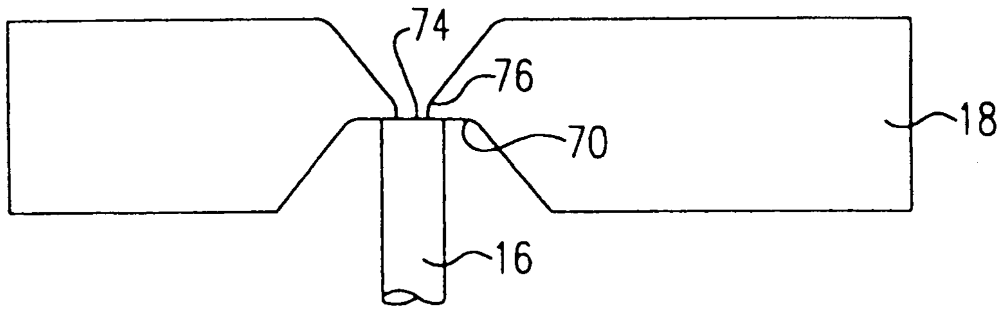

FIG. 12

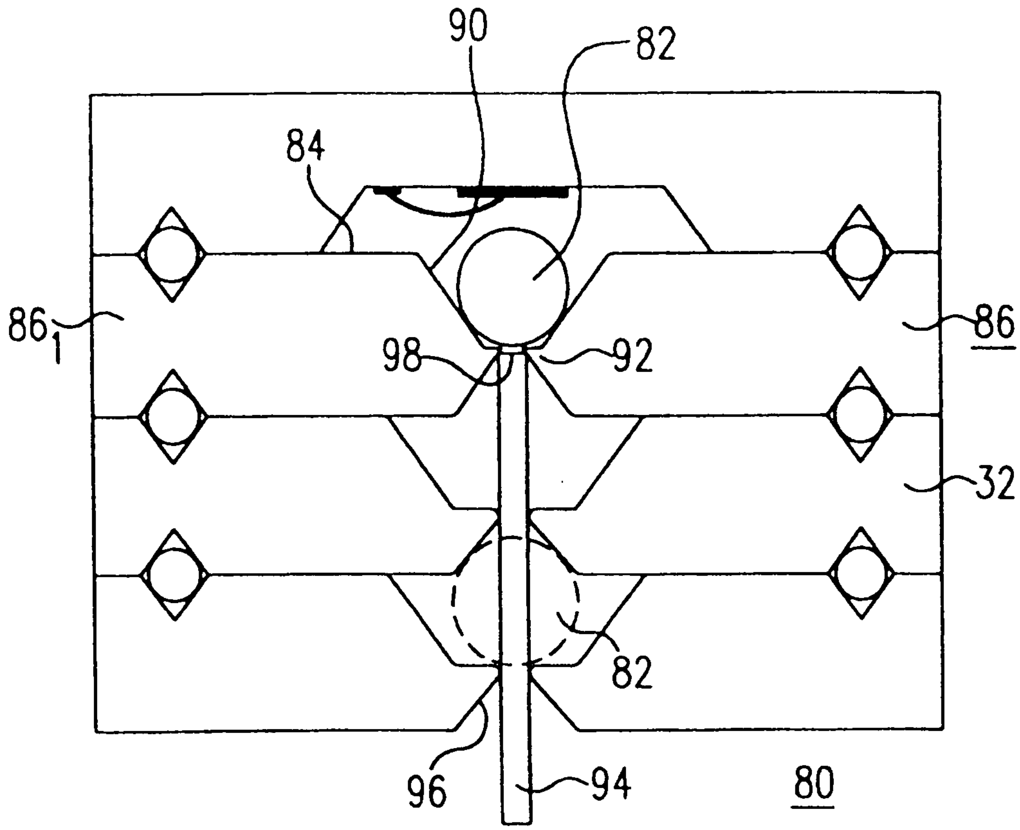

FIG. 10

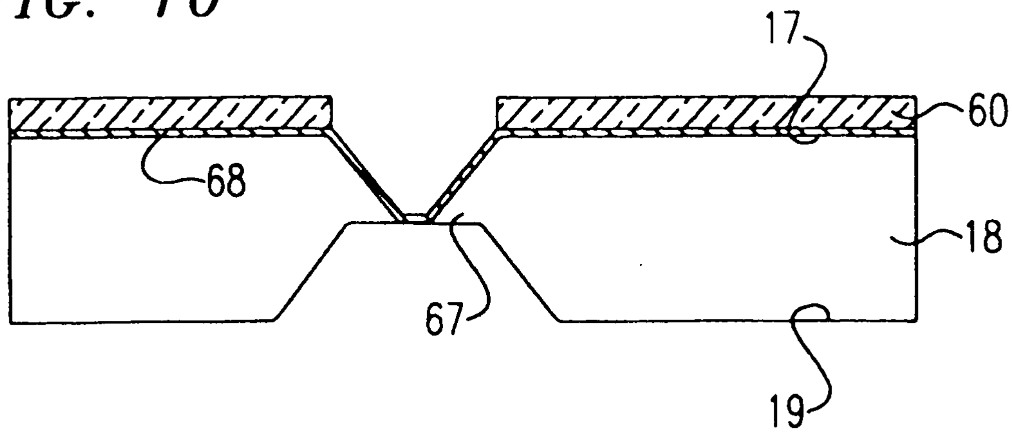

FIG. 11

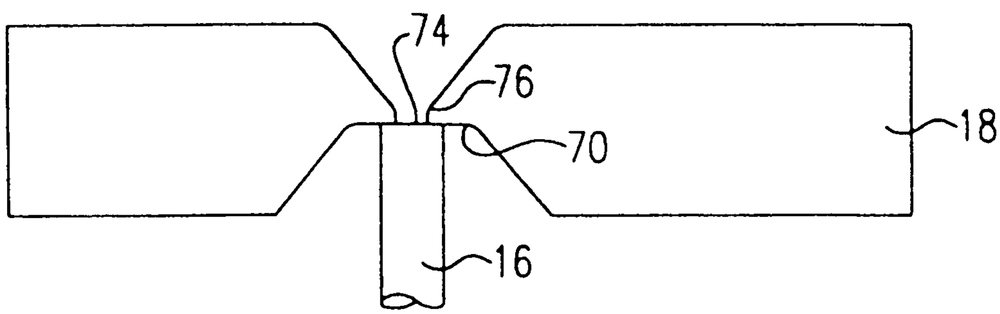

FIG. 12